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(57) Abstract

Method and device for duplex communication in a Code Division Multiple Access (CDMA) communication system, wherein data bits that have been encoded into a number of symbols or chips are transmitted in a first communication direction via a first transmission channel, and in a second communication direction via a second transmission channel. The data bits in the first communication direction are encoded into a larger number of chips than the data bits in the second communication direction, and bits are added to the data bits to be transmitted in the second communication direction, in such a number that in fact identical chip transmission speeds are realised on the first and the second transmission channel. The added bits are combined into at least one separate communication channel in the second communication direction.

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METHOD AND DEVICE FOR CDMA DUPLEX DATA COMMUNICATION

The invention relates to a method for duplex communication in a Code Division Multiple Access (CDMA) communication system, wherein data bits that have been encoded into a number of symbols or chips are transmitted in a first communication direction via a first transmission channel, and in a second communication direction via a second transmission channel.

CDMA or Spread Spectrum (SS) data transmission is known per se in practice. CDMA data transmission, which was initially used for military and other secret communication techniques, is now increasingly used for civil communication as well. Wireless and/or mobile cellular telephone systems are examples thereof.

Spread Spectrum is a transmission technique wherein the signal to be transmitted occupies a greater bandwidth than the bandwidth which is in fact needed for transmitting the data in question. Band spreading is effected by means of an algorithm, in which data bits are encoded into a number of elements or chips, so that each data bit is transmitted as a sequence of symbols. Said symbols may assume the logical value "1" or "0" or frequency variations transmitted in the rhythm of the respective sequence. In the former case the term Direct Sequence CDMA (DS-CDMA) is used, whilst the latter case is referred to as Frequency Hopping CDMA (FH-CDMA). In both cases the signal that has been transmitted can be reconstructed again if the sequence of the transmitted chips or the frequencies are known at the receiver's end. Depending on the size of the sequence, that is, the number of chips in which a bit to be transmitted is encoded, a plurality of independent codes are available, as a result of which several users can use one and the same transmission channel simultaneously, theoretically without interfering each other. Only the user who has the correct code is capable of receiving the data bits transmitted with this code. Band spreading makes the CDMA transmission much less sensitive to various kinds of noise and interference on the transmission channel.

In practice a number of encoding algorithms are known whereby a bit can be encoded with different chip sequence lengths. The use of a specific algorithm and the chip sequence length depend on the type of CDMA data transmission, among other things, wherein basically a

distinction may be made between asynchronous CDMA and synchronous CDMA transmission. In the case of asynchronous CDMA, the various users transmit and receive independently of each other on one channel. In the case of synchronous CDMA, the chip sequences are transmitted under the control of common time control means. It is possible to demonstrate that the channel efficiency of synchronous CDMA is greater than that of asynchronous CDMA, in the case of synchronous CDMA, however, additional circuitry is required for effecting the synchronisation.

For a more detailed explanation of CDMA and Spread Spectrum techniques, reference is made to literature which is known in this field, among which the books "Spread Spectrum Systems with Applications", by R.C. Dixon, John Wiley & Sons, Inc.; 1994, and "CDMA, Principles of Spread Spectrum Communications", by A.J. Viterbi, Addison-Wesley Publishing Company.

In a typical point-to-multipoint communication system, wherein several remote users communicate via a common distribution or switching point, synchronisation problems in the data received from the users arise at the distribution or switching point. That is, data transmitted by the users, who are located at varying distances from the communication distribution or switching point, will not arrive exactly synchronously at the distribution or switching point, partially due to delays caused by amplifiers, repeaters and the like which are used in the transmission channel. Furthermore, the first and second transmission channels which are used for the intended duplex communication may exhibit different transmission characteristics, such as differences in noise level and other interferences.

Consequently there is a need for a method for duplex communication in a CDMA communication system, which enables a high degree of freedom in the selection of encoding algorithm(s) and chip sequence length(s) without actually increasing the complexity of the data transmission, whilst making efficient use of the total transmission capacity of the communication system.

In order to accomplish that objective the invention provides a method wherein the data bits in the first communication direction are encoded into a larger number of chips than the data bits in the second communication direction, and wherein bits are added to the data bits to be transmitted in the second communication direction, in such

a number that in fact identical chip transmission speeds are realised on the first and the second transmission channel, whereby the added bits are combined into at least one separate communication channel in the second communication direction.

The invention is based on the insight that it is important that the chip speeds at which the information is transmitted on the two transmission channels remain identical as much as possible, so as not to influence the complexity of the processing circuitry in a CDMA communication system, in particular a synchronous CDMA communication channel comprising a plurality of remote terminals, to any significant extent. This makes it possible to use highly integrated processing circuitry for the data transmission via said first and said second transmission channel, both at the users' end and at the network end, that is, at the distribution or switching point, because the time control for transmitting data via the second transmission channel, for example, can be derived from the rate at which data are received from the distribution or switching point on the first transmission channel, in particular at the remote terminals.

With the method according to the invention, wherein the data bits to be transmitted via the first and the second transmission channel can be encoded into different numbers of chips, an identical or substantially identical chip transmission speed on the two transmission channels is effected by the addition of extra bits in the communication direction with the lower number of chips per bit, wherein the added bits are combined into one communication channel or into different communication channels, for example for transmitting system data for error correction, synchronisation and/or signalling purposes.The additional bits may also be used for other information purposes, of course.

The method according to the invention thus combines the advantages of identical transmission speeds on the two data channels with the provision of additional information transmission capacity, and, as intended, a free selection of the encoding algorithm and of the encoding sequence length, in order to achieve CDMA transmission which is optimally adapted to the channel characteristics of the first and the second transmission channel.

In another embodiment of the method according to the invention, wherein the chip sequence lengths on the various transmission

channels are n and n+m respectively, one extra bit per modulo (n/m) of transmitted data bits may be added. That is, one extra bit may be added after each block of modulo (n/m) data bits, or the additional bits may be added in blocks after a selected number of modulo (n/m) transmitted data bits. Furthermore, all extra bits may be introduced as one single block into the data flow to be transmitted.

It has been found that in a communication system wherein the communication with users connected to end terminals is controlled from a central distribution or switching point, for example, information transmitted from said distribution or switching point to the end terminals via the first transmission channel, can be efficiently encoded by means of a so-called Hadamard-Walsh algorithm. This type of encoding allows a maximum number of simultaneous transmissions at a specified chip sequence length. Because time control is effected by the central distribution or switching point, no synchronisation problems are experienced, whereas such problems do occur with regard to the trans-missions which the distribution or switching point receives from the remote terminals of the communication system. As already mentioned above, code sequences transmitted from the end terminals will not arrive perfectly synchronously at the distribution or switching point as a consequence of various delays on the transmission paths, which have different lengths and which may have different configurations. These synchronization errors may give rise to decoding errors, because of the fact that no correlation could be established between the received chips and the code word in the receiver, due to the time shift during decoding, so that decoding of the received information is impossible. It has been found that so-called Preferentially Phase Gold encoding sequences are to a large degree insensitive to relatively minor synchronisation errors. This is achieved at the expense of the available chip length, however.

In a preferred embodiment, using the method according to the invention, the information bits on the first transmission channel are encoded with a code having a length of 128 chips in accordance with a Hadamard-Walsh encoding algorithm, and the bits on the second transmission channel are encoded with a code having a length of 127 chips in accordance with a Preferentially Phase Gold encoding algorithm. When data are transmitted at a rate of 64 kb/s, for example, this means that in comparison with the first transmission channel, a total amount of 64,000

fewer chips are transmitted on the second transmission channel. In order to keep the chip transmission speeds on the two transmission channels identical as much as possible, approximately 500 bits/s have to be added to the data flow on the second transmission channel if the above encoding algorithms are used, which bits may be used as (a) separate communication channel(s).

The method according to the invention is in particular suitable for use in communication systems wherein the transmission channels are provided by a Community Antenna TeleVision (CATV) network. In existing networks the first transmission channel for data transmission from a (central) distribution or switching point to a plurality of end terminals is thereby realised in a higher frequency band than the second transmission channel from the end terminals to the distribution or switching point. Said second transmission channel is realised in a relatively low frequency band. This arrangement can be traced back to the origin of CATV networks, which were originally conceived as one-way distribution networks, and to which a return path on a low frequency band, which experienced relatively little attenuation, was added at a later stage. This was done in order that it would suffice to use amplifiers having a relatively low gain factor, so as to reduce interference and other disturbances caused by high output values as much as possible. This frequency band, however, is relatively sensitive to interference caused by external radiation on components of a lesser quality, such as terminal boxes and junction boxes that may have been installed by the user himself. By using the CDMA transmission technique, which is relatively insensitive to this type of interference, it is possible to realise a technically efficient and economically exploitable communication system via a CATV network.

Comparable interference problems can also be expected in the case of data transmission via electricity distribution networks, such as the 220/380 V electricity grid, and traction networks for trains and trams, for example, which can be upgraded into full-fledged data transmission networks by using the CDMA transmission technique in accordance with the method according to the invention.

However, the method according to the invention can also be used in modern CATV networks, wherein a fully passive transmission band in the frequency range of up to approximately 70 MHz has been realised, and wherein both transmission channels can use this passive transmission

band.

Consequently it is another object of the invention to provide a CDMA communication system for duplex communication, which comprises transmitter-receiver means provided with modulator means for encoding data bits to be transmitted into a number of chips in accordance with a predetermined code, and with demodulator means for decoding data bits in accordance with the predetermined code from chips that have been received, a first transmission channel for transmission in a first communication direction, and a second transmission channel for transmission in a second communication direction, characterized in that the modulator means for transmission via the first transmission channel are arranged for encoding the data bits into a larger number of chips than the modulator means for transmission via the second transmission channel, comprising first means, which are operatively connected to the modulator means for transmission via the second transmission channel, for adding such a number of bits to the data bits to be transmitted that in fact identical chip transmission speeds are realised on the first and the second transmission channel, and second means, which are operatively connected to the demodulator means for transmission via the second transmission channel for retrieving the added bits from the bits that have been transmitted, which added bits form at least one separate communication channel in the second communication direction.

In the communication system according to the invention the timing for the modulator and the demodulator means can be retrieved advantageously from the received data bits. In another embodiment of the invention the modulator means for transmission via the first transmission channel and the demodulator means for transmission via the second transmission channel are connected to system clock means for time control of the bit transmission, and the modulator means for transmission via the second transmission channel and the demodulator means for transmission via the first transmission channel are arranged for time control of the transmission under the control of time control information retrieved from the first transmission channel.

The invention will be explained in more detail hereafter with reference to an embodiment of a communication system via a CATV network, without being limited thereto, however. The invention can also be advantageously realised in an electricity distribution network and other

like networks.

Figure 1 shows a simplified block diagram of a Direct Sequence CDMA (DS-CDMA) system.

Figures 2a, 2b show simplified block diagrams of a conventional CATV network and an improved one, respectively.

Figure 3 schematically illustrates the method according to the invention in a CATV network.

Figures 4a, 4b show illustrative diagrams of a transmitter-receiver according to the invention, which is intended for use in a distribution or switching point of a CATV network.

Figures 5a, 5b show illustrative diagrams of a transmitter-receiver for use in an end terminal of a CATV network.

Figure 6 shows an example of a CDMA channel structure for use in a communication system according to the invention.

As already discussed in the introduction, the two most widely used forms of Code Division Multiple Access (CDMA) or Spread Spectrum (SS) are so-called Frequency Hopping CDMA (FH-CDMA) and Direct Sequence CDMA (DS-CDMA). The discussion hereafter is based on DS-CDMA. The invention is by no means limited to this form, however.

Figure 1 shows a simplified block diagram of a DS-CDMA system comprising a transmission channel 1, a transmitter 2 and a receiver 3. Channel 1 may be a wired communication channel, an optical communication channel, or a wireless communication channel, among which a radio channel, an infrared channel and an ultrasonic channel. As is known to those skilled in the art, a transmission channel can be represented mathematically by a time delay τ_j 4 and a noise source 5.

In a CDMA communication system a number j of users simultaneously transmit information via the transmission channel, as is represented by means of a summation block 6, which operates on an assumed number of users 8 of j = 1 - N. In that case the total signal on the transmission channel is made up of the sum of noise source 5 and the signals of users 8, as is schematically indicated by summator 7. A more detailed model may proceed from a separate noise source for each individual user.

Transmitter 2 essentially consists of a modulator 9, which comprises an input 10, to which data bits to be transmitted are fed. Modulator 9 processes the data bits into signals which are suitable for

transmission via transmission channel 1. Receiver 3 comprises a demodulator 11, which is provided with an output 12 for delivering the transmitted demodulated data bits.

For transmission according to the DS-CDMA principle the data bits to be transmitted from a transmitter 2 to a receiver 3 by a user j are each encoded into a number of symbols or chips with a code $C^N j$ (t), which is generated by means of a code generator 13 and mixer 14 . A logic "1" is for example represented by the code itself, and a logic "0" is for example represented by the inverse of the code. The longer the code, the more the signal to be transmitted will resemble a noise signal.

The broadband DS-CDMA signal from user j, the frequency of which has been spread in this manner, can be reconstructed after the transmission delay time τ_j at receiver 3, via a similar code generator 13 $C^N j$ $(t-\tau_j)$ and mixer 14, provided the code by which the data bits have been encoded for the j^{th} user is known.

Those skilled in the art will appreciate that when unique codes are used for distributing and/or spreading of data bits, data from several users can be transmitted simultaneously via the same transmission channel. The transmission capacity of a DS-CDMA system is at maximum when the various data transmissions can be mutually synchronized. The transmission capacity is also influenced by the modulation technique that is used on the transmission channel.

By spreading the data bits over a larger system bandwidth, the influence of narrow-band interference on the signal that is eventually retrieved is considerably reduced. Accordingly, DS-CDMA is excellently suited for use in communication systems with narrow-band interference signals. The CDMA signal from each active user furthermore adds to the background noise, which affects all system users. By selecting a set of unique spreading codes, that is, spreading codes having a small cross correlation, the extent to which the users influence each other is reduced to a minimum.

Typical communication systems with narrow-band interference signals are the so-called Community Antenna TeleVision (CATV) networks, a conventional configuration of which is schematically shown in Figure 2a, whilst Figure 2b shows a diagram of an improved network configuration. In the network structure 15 shown in Figure 2a, information is transmitted from a main station or head-end 16 to end terminals 17.

Various bidirectional amplifiers 18, 19, 20 are connected between the head-end 16 and end terminals 17, which amplifiers function to eliminate transmission losses in network 15, which is conventionally built up of coaxial cable 22.

In the illustrated embodiment the amplifiers 18 are connected to the head-end 16 in the form of a so-called ring network, whereby the signals that are received from an amplifier 18 are further distributed in a district station 21 via a group amplifier 19. The users or end terminals 17 are radially connected to an output amplifier 20, which receives signals from a group amplifier 19.

In Dutch CATV networks the amplifiers 18, 19 and 20 are generally arranged in such a manner that they pass signals from the head-end 16 to end terminals 17 in a broad frequency band from approximately 50 MHz to over 750 MHz. The transmission direction from the head-end 16 to end terminals 17 is also referred to as the downstream direction. In the other direction, that is, from end terminals 17 to the head-end 16, also referred to as the upstream direction, a transmission frequency band of 5 MHz to approximately 50 MHz is available. The object is to achieve a fully passive transmission frequency band in the frequency range of up to approximately 70 MHz, that is, without amplifiers.

Figure 2b shows an improved CATV network structure 25, wherein the head-end 16 and the associated amplifiers 18 have been substituted for a system of receiving and switching stations 26, which are interconnected in a ring structure via a duplex (or bidirectional) glass fibre transmission system 23, 24. Such an improved CATV network 25 is suitable for data transmission of broadband data services, which are transferred according to the Integrated Services Digital Network (ISDN) or the Asynchronous Transfer Mode (ATM) technology.

Coaxial cable 22, group amplifiers 19 and output amplifiers 20 and the associated transmission frequency bands are still widely used, also in improved CATV networks 25, on the path from a switching station 26 to the end user 17.

It has been found that it is in this part of the CATV network that objectionable narrow-band interference signals may occur. They occur in particular in the upstream part of the transmission band, between 5 - 15 MHz. The influence of this narrow-band interference signals can be minimized, however, by using the above-described DS-CDMA technique

for data transmission. Data are thereby transmitted in a first communication direction to end terminals 17 via a first transmission frequency band, under the control of a head-end 16 or a switching station 26, and data are transmitted in a second communication direction to the head-end 16 or a switching station 26 by end terminals 17 via a second transmission frequency band.

Those skilled in the art will appreciate from Figures 2a/b that the transmission channels from the head-end 16 or a switching station 26 to the individual end terminals 17 may be different in length, said length depending on the extent and the scale of the CATV network. Consequently, chip sequences that are transmitted under the control of the head-end 16, for example, will not arrive simultaneously or synchronously at each end terminal 17. Conversely, data transmitted by end terminals 17 will not arrive synchronously at the head-end 16.

As already indicated in the foregoing, the transmission capacity of a CDMA communication system depends not only on the synchronous transmission of the code sequences, but also on the uniqueness of the sequences among themselves, that is, the degree of mutual correlation between the sequences. The degree of correlation is determined not only by the configuration of the various codes, but also by the number of chips with which the data bits are distributed. The better the various data signals of the various end terminals are synchronized, the higher the number of chips may be.

The invention is based on the insight that the data bits in the first, downstream communication direction can be encoded with a larger number of chips than those in the second, upstream communication direction. This is caused by the fact that the code sequences in the downstream direction are transmitted from the head-end 16 or a switching station 25 in a synchronized manner, whilst the code sequences which the head-end 16 or a switching station 25 receives from the individual end terminals 17 do not arrive synchronously, due to various delays on the various transmission channels.

The invention is schematically illustrated in Figure 3, wherein it is assumed that CDMA data transmission takes place via a CATV network 15, 25 (Figures 2a/b). Data are transmitted in a first, downstream communication direction from a head-end 16 or switching station 26 to an end terminal 17 via a first transmission channel 27. Data are

transmitted in a second, upstream communication direction from an end terminal 17 to the head-end 16 or a switching station 26 via a second transmission channel 28. The CATV network 15; 25 may thereby be configured as shown in figures 2a/b.

In a practical CATV network, for example a network that is operative in the Netherlands, the first transmission channel may be realised in the downstream transmission band, which ranges from approximately 50 MHz to over 750 MHz. The second transmission channel may be realised in the upstream transmission band, which ranges from approximately 5 MHz to 50 MHz. It has been found that substantial narrow-band interference may occur in the upstream frequency range from 5 to 15 MHz, which also influences the selection of CDMA encoding on the second transmission channel.

The head-end 16 or switching station 26 comprises transmitter-receiver means, which are provided with means 29 for CDMA encoded transmission of data bits via the first transmission channel 27 to end terminals 17, and with means 30 for retrieving data bits from the information received from end terminals 17 via second transmission channel 28. End terminals 17 comprise transmitter-receiver means, which are provided with means 31 for CDMA encoded transmission of data bits to the head-end 16 or a switching station 26 via the second transmission channel 28, and with means 32 for decoding CDMA encoded information from the first transmission channel 27. Means 29 and 31 may have a configuration similar to that of the receiver 3 as shown in Figure 1.

In the preferred embodiment of the invention, means 29 and 32 are arranged for the transmission of data bits on the first transmission channel 27 in accordance with a Hadamard-Walsh CDMA code having a chip length of 128, and means 30 and 31 are arranged for the transmission of data bits on the second transmission channel 28 in accordance with a Preferentially Phase Gold CDMA code having a chip length of 127.

A set of N unique or orthogonal code sequences having length N is obtained by the rows of an N x N orthogonal matrix: $C = \left[C^{N}_{j.i} \right]$ with $C_{j,i} \in {}^{N}\left\{ -1.1 \right\}$, which is called a Hadamard matrix. This number N of orthogonal sequences is the maximum for a sequence length N. Hadamard matrixes (Walsh codes) are only optimal for use in CDMA for synchronisation errors of less than one chip period.

As is shown in Figure 3, data are transmitted synchronously from the head-end or switching station 26, via the first transmission channel 27, under the control of time control means 33. Consequently, Hadamard-Walsh encoding can be used advantageously in order to achieve a maximum transmission capacity in the first communication direction.

In the preferred embodiment of the invention Preferentially Phase Gold codes having a chip length of 127 are used for transmission via the second transmission channel 28. It can be demonstrated that these codes are less sensitive to synchronisation errors and that they are optimal in the sense that there are no larger sets of sequences providing the same unique properties for transmission via incompletely synchronised transmission channels. For a more detailed discussion of Gold codes reference is made to the article "Optimal binary sequences for spread spectrum multiplexing" by R. Gold, IEEE Transactions on Information Theory, 13(4), October 1967, and "Definition of the mobile network synchronisation experiment, final study report", by W.R. Braun et al, Technical report ESA-ESTEC, Noordwijk, the Netherlands, November 1990.

By using Preferentially Phase Gold codes for data transmission via the second transmission channel 28, on which the transmissions from the various end terminals 17 arrive unsynchronised at the head-end 16 or switching station 26 due to mutually different delays, as described above, also the transmission on the second transmission channel 28 can take place in an optimally efficient manner.

In order to prevent the use of separate time generator means, which for example necessitates the use of external synchronisation signals from satellites or atomic clock transmitters in the transmitter-receiver means in end terminals 17, the transmitter-receiver means in end terminals 17 are provided with time control means 34, which retrieve time control information from data that have been received via the first transmission channel 27.

A problem occurs thereby, however, because if a 128 chip code is used on the first transmission channel 27, and a 127 chip code is used on the second transmission channel 28, 64,000 fewer chips will be transmitted on the second transmission channel 28 than on transmission channel 27 if the data bit rate is for example 64 kb/s. This would require an adaptation of the time control means 34, because the time

control information retrieved from the first transmission channel cannot be simply used for time control of the transmission from an end terminal 17 on the second transmission channel 28, due to the difference in the number of chips to be transmitted.

Particularly in the case of duplex communication systems comprising a large number of end terminals 17, it applies that an economically sound and exploitable communication system will be obtained only if the transmitter-receiver means in the end terminals 17 are not unnecessarily complex, and if as many components as possible can be integrated into a single device.

In order to achieve this, according to the invention means 35 are connected to the transmitter-receiver means in an end terminal 17, which means are operative to add bits to the data bit stream on the second transmission channel 28, so as to synchronise the chip transmission speed on the two transmission channels 27 and 28 as much as possible. In such a manner, that the time control information retrieved from the first transmission channel 27 by the time control means 34 can be used directly for controlling the transmission on the second transmission channel 28.

In the preferred embodiment of the invention, with data bit streams of 64 kb/s, 64,000/127~500 bit/s have to be added via means 35.

In the head-end 16 or switching station 26, means 36 retrieve the added bits from the data bit stream that has been transmitted via the second transmission channel 28.

In accordance with the invention these bits may be added to the data bits separately, in various blocks, or as one block, and be used as a separate communication channel or as communication channels for transmitting, for example, system information, signalling information, synchronisation information, etc. from an end terminal 17.

The method according to the invention therefore offers two direct advantages, that is, the time control information retrieved from the first transmission channel 27 can be used directly for controlling the transmission via the second transmission channel 28, whilst the extra bits can be used as (a) useful additional communication channel(s).

Those skilled in the art will appreciate that instead of using the above-mentioned preferred encoding techniques and chip lengths, it is also possible to use other codes with other chip lengths

that are suitable for CDMA transmission.

Generally it applies that if the bits to be transmitted via the second transmission channel 28 are encoded into n chips, and the bits to be transmitted via the first transmission channel are encoded in n+m chips, one additional bit per modulo (n/m) of transmitted bits is added on the second transmission channel. If the channel capacity is used efficiently, it will generally apply that m << n.

Figure 4a is a block diagram of a preferred embodiment of transmitter means 40 for use in accordance with the invention in a distribution or switching point in a transmission network, such as the head-end 16 or switching station 26 of a CATV network 15 or 25 (Figures 2a/b).

A data signal fed to an input 41 of transmitter means 40 is differentially encoded by means 42 and split in a known manner into an In phase (I) data flow and a Quadrature phase (Q) data flow, both at half bit rate. The arriving serial data flow 41 is also converted into a parallel data bit stream. The I and Q data flows are converted into CDMA encoded chip sequences in a signal encoding unit 44, via a code generator 45, in such a manner that each data flow towards a user can be encoded with different I and Q codes. Said encoding takes place under the control of time control means 43.

Data from other users 48 are subjected to CDMA encoding in a similar manner, with this difference, however, that other unique code sequences are used. The I and Q chip sequences in question are combined into joint I and Q chip sequences by summators 46 and 47. These I and Q chip sequences are then processed by a sample-and-hold circuit 49, digital pulse shaping means 50, for example in the form of a so-called square root raised cosign bandpass filter, to give them a pulse shape that is suitable for transmission via the first transmission channel.

Those skilled in the art will appreciate that the holding function of circuit 49 may also be performed by the D/A converter 51, and that circuit 49 may be configured only as a sampling circuit, especially as a so-called "oversampling circuit".

The I and Q chip sequences thus formed are modulated into I and Q carrier components in an analog modulator 53 in a known manner, by means of an oscillator 54 and a phase shifter 55 respectively. The I and Q components are then combined by means 56 and, after filtering

by a bandpass filter 58, delivered on a transmission carrier from oscillator 57 to an output 59 of the transmitter means 40 for transmission via the first transmission channel.

The time control means 43 are shared by all users 48, so that a synchronized CDMA encoded bit stream is automatically transmitted from a distribution or switching point of a communication system. Since the encoded signals are added in the digital domain prior to the analog modulation, a single analog modulator 53 with transmission carrier generator 57 will suffice. This solution is advantageous with regard to the retrieval of the carrier wave and a coherent detection at the demodulator means in the end terminals of the communication system.

As has been discussed in the foregoing, the code generator 45 of the preferred embodiment of the invention is arranged for encoding bits by means of a Hadamard-Walsh CDMA code having a chip length of 128.

Figure 5a shows a block diagram of a transmitter 60 for use in an end terminal of a communication system, for example an end terminal 17 of the CATV networks shown in Figures 2a/b.

Transmitter 60 generally corresponds with the transmitter 40 as described above and as illustrated in Figure 4a, with this difference that only one data flow on an input 61 of transmitter 60 is delivered to an output 62 of transmitter 60 as a CDMA encoded chip sequence.

Since transmitter 60 transmits information in another frequency band on a second transmission channel, oscillator 57 and bandpass filter 58 in analog modulator 63 will work at other frequencies than oscillator 57 and bandpass filter 58 in the analog modulator 53 of transmitter 40.

Signal encoding unit 64 comprises a code generator 65, which, in the preferred embodiment of the invention, delivers a Preferentially Phase Gold CDMA code for encoding the I and Q bit streams. Unlike transmitter 40, code generator 65 in transmitter 60 is time-controlled by time control information that is retrieved from the first transmission channel of the communication system, as is indicated by signal arrow 66, on an input of control means 67, to which also information from a control channel of the communication system may be fed, as is indicated by signal arrow 58. Information with regard to the transmission power to

be delivered by the analog modulator 63 can be fed to transmitter 60 via this control channel, for which controllable amplifier means 69, whose gain can be adjusted by the control means 67, are incorporated in the analog modulator 63.

Figure 5b shows a block diagram of a preferred embodiment of a receiver 70 for use in an end terminal of a communication system.

The signal received on an input 71 of an analog demodulator 72 is converted into an intermediate frequency in a known manner, by means of a mixer comprising an oscillator 74 and a bandpass filter 75. Oscillator 74 and bandpass filter 75 are tuned for reception on the first transmission channel, in accordance with the tuning of oscillator 57 and bandpass filter 58 in transmitter 40. Then the intermediate frequency signal is converted into I and Q baseband signals, to which end the modulation carrier is retrieved from the intermediate frequency signal by means of a carrier retrieval circuit 76. The I and Q baseband chip sequences are fed to a signal decoding unit 80 via low-pass filters 77, Analog/Digital (A/D) converters 78 and pulse recovery circuits 79.

Decoding unit 80 operates to reconstruct the transmitted bits from the CDMA encoded chip sequences that are received. Said reconstruction takes place by multiplication of the baseband I and Q sequences with replica of the I and Q codes used for encoding the bits in transmitter 40.

Signal decoding unit 80 is configured as an interpolation/decimation circuit comprising interpolation filters 81, which are in fact digital low-pass filters, sampling means 82, 83, summators 84 and a code generator 85, of the same type as code generator 45 in transmitter 40.

Decoding unit 80 works in such a manner that the I chip flow is split up into a first and a second chip flow, wherein the first chip flow undergoes further processing and delivers the reconstructed bit stream via a combined data detection, parallel-series and decoding circuit 88 to an output 89 of receiver 70. The second I chip flow, which may lead or lag with respect to the first I chip flow, and the output signal from a circuit 87 that detects whether the first I chip flow results in the retrieval of data bits, are processed into a time control signal for the

so-called down sampling circuits 82 and the time control means 67 of transmitter 60 in a time control retrieval circuit 86, as is indicated by signal arrow 66. See also Figure 5a. Means 87 also control the amplification of the received signal in the analog demodulator 72 via controllable amplifier means 73 and the code generator 85 in signal decoding unit 80. The time control signal retrieved by the retrieval circuit 86 is adjusted with each data bit that is received, such that a precise retrieval of the timing signal is effected.

Figure 4b shows a receiver 90 for use in a distribution or switching point of the communication system, such as the head-end 16 or switching station 26 of a CATV network 15, 25. The operation of the receiver 90 largely corresponds with the operation of receiver 70, since the various bit streams from the end terminals or the transmitters have independent frequencies and phases, however, no carrier wave retrieval can take place before the CDMA signals have been decoded. Consequently, analog demodulator 92 comprising input 91 is not provided with a modulation carrier retrieval circuit 76, but with an oscillator 54 and phase shifter 55 tuned for reception on the second transmission channel. Signal decoding unit 93 is arranged for retrieving the various data flows via a digital phase-lock loop 94, which data flows are delivered in serial form to outputs 95 of receiver 90. By using demodulation in the digital domain a single analog demodulator 92 in receiver 90 will suffice. Digital phase-lock loop 94 comprises a circuit 96 for estimating phase errors between the decoded chip sequences and the chip sequences from code generator 98 in signal decoding unit 93, and so-called complex phase rotation circuits 97, which rotate the arriving chips through an estimated phase in the complex plane. The real portion of the phase-rotated complex signal is used for retrieving data bits, whilst the imaginary portion is used for producing an error signal. The error signal is used for making an estimation of the complex phase of the arriving chip flow.

Via a code control circuit 99, a signal is retrieved from the chip flows being received, which signal is a measure for the signal strength of the received chips, and which can be transmitted to receiver 60, via a control channel, as described above and indicated by signal arrow 68 (see Figure 5a).

Although the transmitters and receivers that have been described with reference to Figures 4 and 5 transmit the chips in QPSK

(Quadrature Phase Shift Keying) modulation, it is also possible to user other modulation methods, of course, such as the methods known by acronyms BPSK, M-ASK, M-PSK, M-FSK and M-QAM. It is also possible to use non-coherent modulation and demodulation instead of the above-described coherent detection techniques.

According to the invention transmitter 60 comprises means 100 for adding bits to the bit stream, in order to have the chip transmission speed on output 62 correspond with that on output 59 of transmitter 40 as much as possible. As a result of this, the time control information 66 which is retrieved from the chip flow which receiver 70 receives on its input 71 can be fed directly to transmitter 60, as described above.

Receiver 90 comprises means 101 by which the added bits can be retrieved from the data flow being received, so that one or more separate communication channels are obtained, which can be used for transmitting system information, synchronisation information, etc., as described above.

Since the modulators and demodulators are implemented practically completely digitally, they can be integrated into so-called Application Specific Integrated Circuit (ASIC) modems, which is highly advantageous from an economical point of view.

Figure 6 shows an example of a CDMA channel structure for transmitting information from a distribution or switching point in a communication system according to the invention. In this example three control channels are provided, a pilot channel 110, a synchronisation channel 111, a paging channel 112, as well as a plurality of data channels 113. Each channel possesses digital signal decoding means 114 and filter and D/A converter circuits 115, as described above in connection with Figure 4a. The I and Q components of the various channels are combined by summator means 116 and 117 into I and Q chip flows for further processing by an analog modulator.

In accordance with the preferred embodiment of the invention the pilot channel 110 can be encoded by Walsh code 0, as is indicated by signal arrow 118. The synchronisation channel may for example be encoded by Walsh code 64, arrow 119, and the paging channel may be encoded by Walsh code 1, arrow 120. Channels 113 may be encoded with the other Walsh codes 2-63, 65, 128, as is indicated by signal arrow 121,

whereby it is assumed that 128 chip Hadamard-Walsh codes are available, which results in a maximum of 128 simultaneously operative CDMA connections.

CLAIMS

1. A method for duplex communication in a Code Division Multiple Access (CDMA) communication system, wherein data bits that have been encoded into a number of symbols or chips are transmitted in a first communication direction via a first transmission channel, and in a second communication direction via a second transmission channel, characterized in that the data bits in the first communication direction are encoded into a larger number of chips than the data bits in the second communication direction, and wherein bits are added to the data bits to be transmitted in the second communication direction, in such a number that in fact identical chip transmission speeds are realised on the first and the second transmission channel, whereby the added bits are combined into at least one separate communication channel in the second communication direction.

2. A method according to claim 1, characterized in that a bit to be transmitted via the second transmission channel is encoded into n chips, and a bit to be transmitted via the first transmission channel is encoded in n+m chips, whereby n and m are integers, with $m \ll n$.

3. A method according to claim 2, characterized in that one extra bit per modulo (n/m) of data bits is added.

4. A method according to claim 2, characterized in that said extra bits are added to the data bits in blocks.

5. A method according to any of the preceding claims, characterized in that the added bits are used for controlling the communication, in particular for error correction, synchronisation and/or signalling purposes.

6. A method according to any of the preceding claims, characterized in that the communication system is arranged for transmission from a distribution or switching point, via the first transmission channel, to a plurality of end terminals, and for transmission from end terminals, via the second transmission channel, to the distribution or switching point under the control of time control information retrieved from the first transmission channel, wherein the bits to be transmitted via the first transmission channel are encoded in accordance with a Hadamard-Walsh CDMA code, and wherein the bits to be transmitted via the second transmission channel are encoded in accordance with a Preferentially Phase Gold CDMA

code.

7. A method according to claim 6, characterized in that said Hadamard-Walsh CDMA code has a chip length of at least 128 and said Preferentially Phase Gold CDMA code has a chip length of at least 127.

8. A method according to claim 6 or 7, characterized in that the communication system comprises a Community Antenna TeleVision (CATV) network.

9. A method according to claim 6, 7 or 8, characterized in that the communication system comprises an electricity distribution network, among which a distribution network for electric traction.

10. A Code Division Multiple Access (CDMA) communication system for duplex communication, comprising transmitter-receiver means provided with modulator means for encoding data bits to be transmitted into a number of chips in accordance with a predetermined code, and with demodulator means for decoding data bits in accordance with said predetermined code from chips that have been received, a first transmission channel for transmission in a first communication direction, and a second transmission channel for transmission in a second communication direction, characterized in that said modulator means for transmission via the first transmission channel are arranged for encoding the data bits into a larger number of chips than the modulator means for transmission via the second transmission channel, comprising first means, which are operatively connected to the modulator means for transmission via the second transmission channel, for adding such a number of bits to the data bits to be transmitted that in fact identical chip transmission speeds are realised on the first and the second transmission channel, and second means, which are operatively connected to the demodulator means for transmission via the second transmission channel for retrieving the added bits from the bits that have been transmitted, which added bits form at least one separate communication channel in the second communication direction.

11. A CDMA communication system according to claim 10, characterized in that the modulator means for transmission via the second transmission channel are arranged for encoding a bit to be transmitted into n chips, wherein the modulator means for transmission via the first transmission channel are arranged for encoding a bit into n+m chips, and wherein n and m are integers, with m << n.

12. A CDMA communication system according to claim 11, characterized in that said first and said second means are arranged for respectively adding and removing one extra bit per modulo (n/m) of data bits.

13. A CDMA communication system according to claim 10 or 11, characterized in that said first and said second means are arranged for respectively adding and removing extra bits in blocks.

14. A CDMA communication system according to any of the claims 10 - 13, characterized in that the modulator means for transmission via the first transmission channel and the demodulator means for transmission via the second transmission channel are connected to system clock means for time control of the transmission, and that the modulator means for transmission via the second transmission channel and the demodulator means for transmission via the first transmission channel are provided with means for time control of the transmission under the control of time control information retrieved from the first transmission channel.

15. A CDMA communication system according to any of the claims 10 - 14, characterized in that the modulator means for transmission via the first transmission channel are arranged for transmission of bits encoded in accordance with a Hadamard-Walsh CDMA code, and that the modulator means for transmission via the second transmission channel are arranged for transmitting bits encoded in accordance with a Preferentially Phase Gold CDMA code.

16. A CDMA communication system according to any of the claims 10 - 15, characterized in that the first and the second transmission channel comprise transmission channels made up of a Community Antenna TeleVision (CATV) network, wherein the modulator means for transmission via the first transmission channel and the demodulator means for transmission via the second transmission channel are arranged in a distribution or switching centre of the CATV network, and wherein the modulator means for transmission via the second transmission channel and the demodulator means for transmission via the first transmission channel are arranged at a plurality of end terminals of the CATV network.

17. A CDMA communication system according to any of the claims 10 - 15, wherein the first and the second transmission channel comprise transmission channels made up of an electricity distribution network, among which a distribution network for electric traction, wherein

the modulator means for transmission via the first transmission channel and the demodulator means for transmission via the second transmission channel are arranged in a distribution or switching centre of the electricity distribution network, and wherein the modulator means for transmission via the second transmission channel and the demodulator means for transmission via the first transmission channel are disposed at a plurality of end terminals of the electricity distribution network.

18. Modulator means and demodulator means for use in a CDMA communication system according to any of the claims 10 - 17, which means are arranged for transmitting bits in accordance with a predetermined CDMA code, and which are provided with means for adding extra bits to data bits to be transmitted.

19. Modulator means and demodulator means for use in a CDMA communication system according to any of the claims 10 - 17, which means are arranged for transmitting bits in accordance with a predetermined CDMA code, and which are provided with means for retrieving, from received bits, the extra bits that have been added thereto.

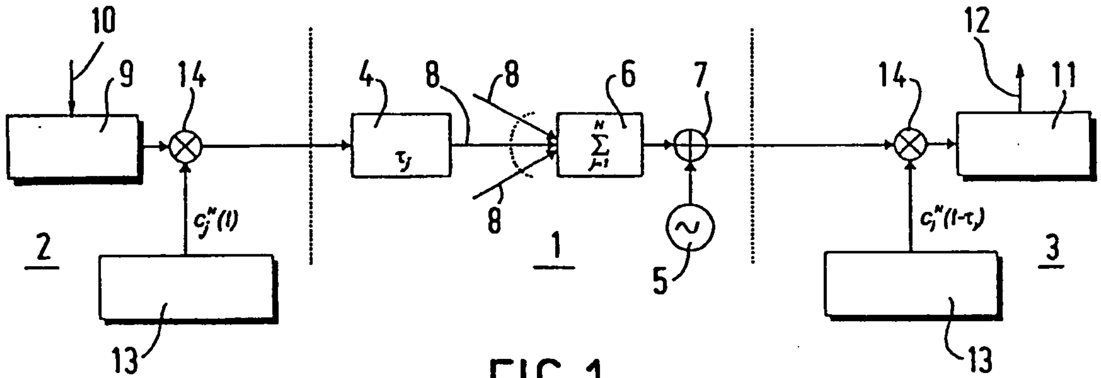


FIG. 1

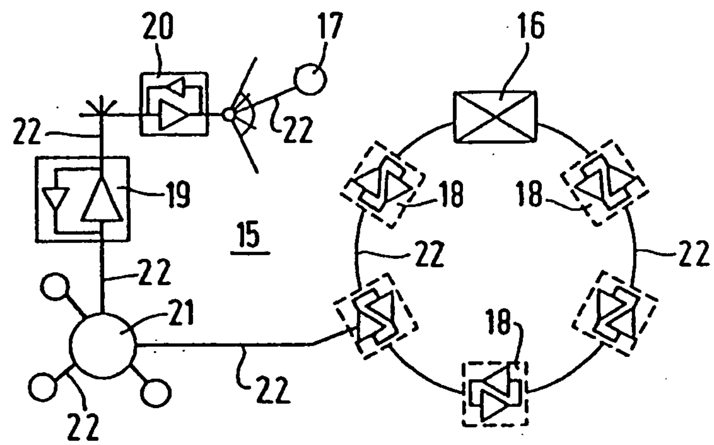


FIG. 2a

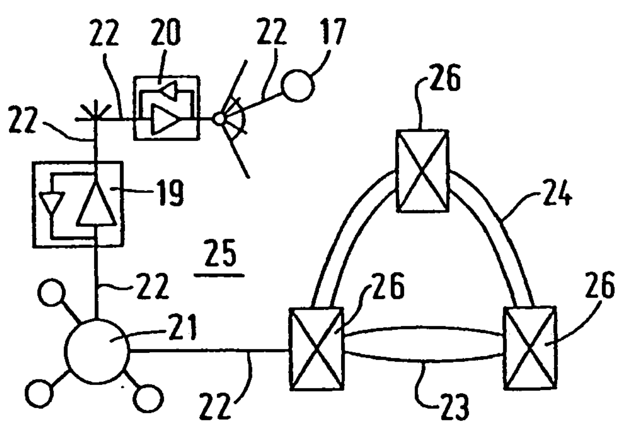
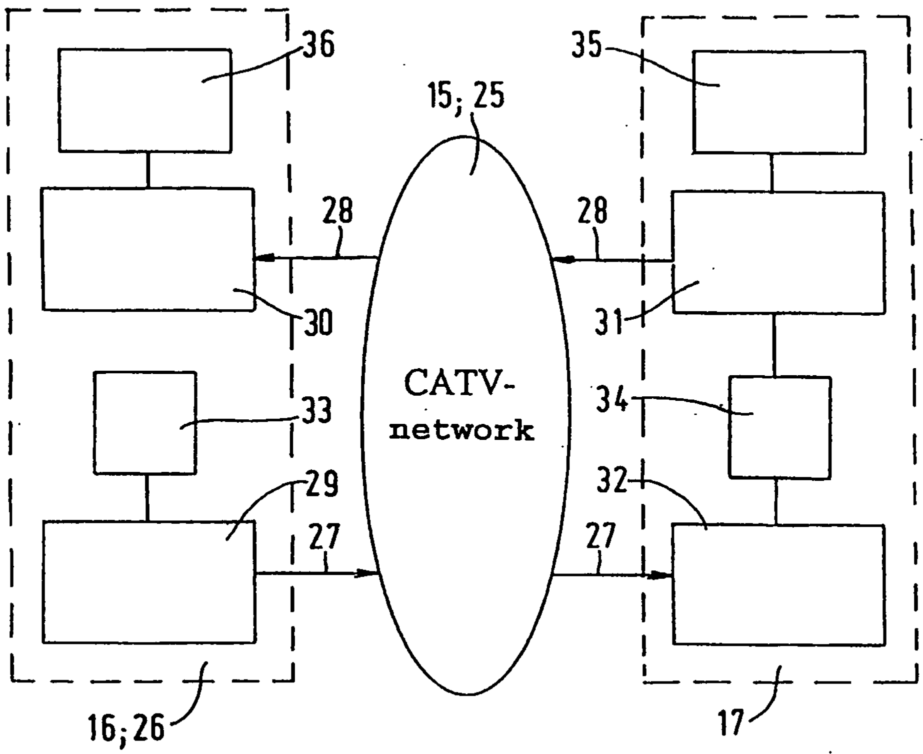


FIG. 2b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31
CATV-
network
33
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16; 26
17

FIG. 3

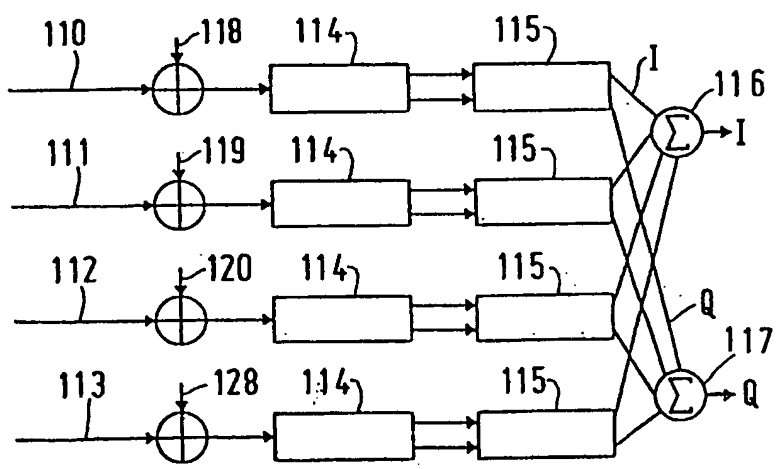
110
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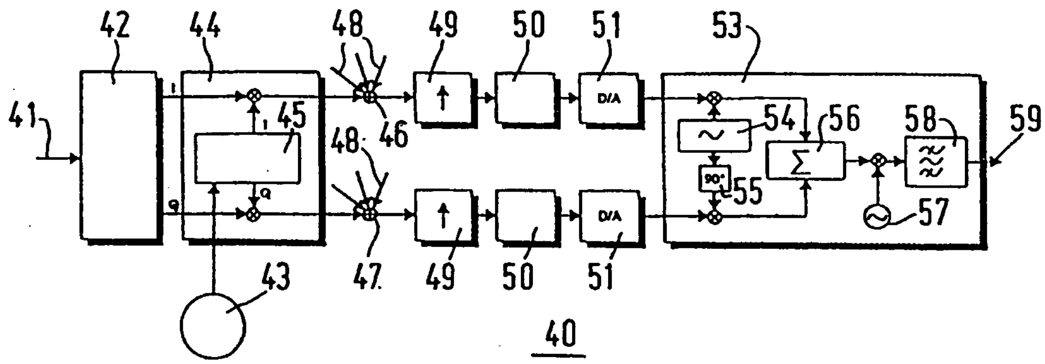
FIG. 6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D/A
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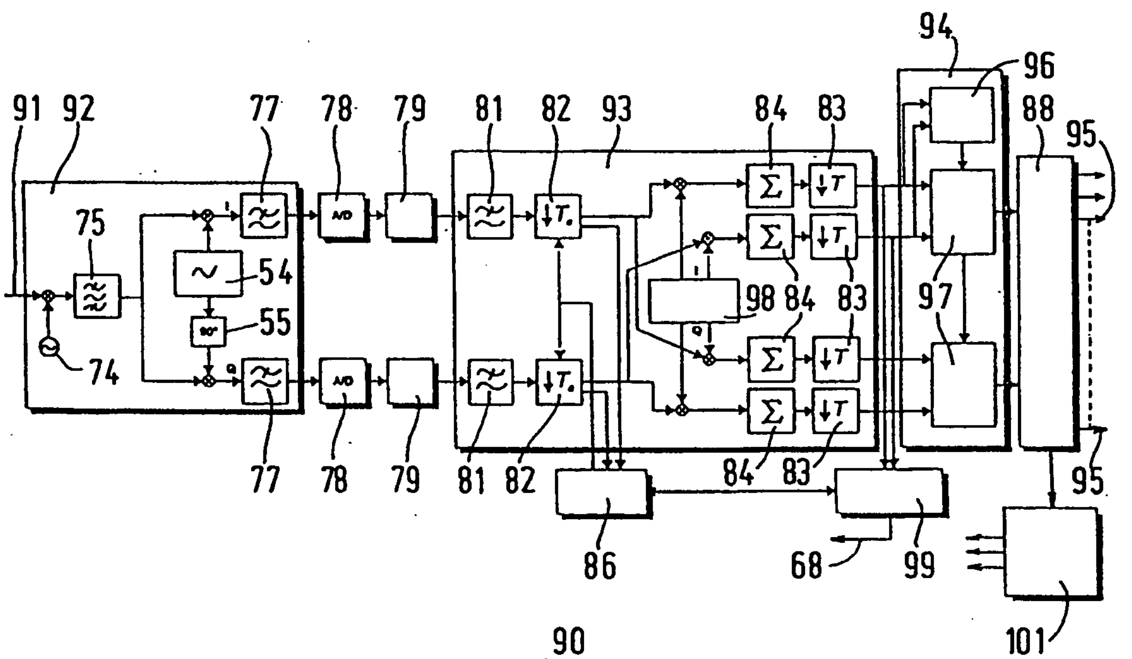
FIG. 4a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68
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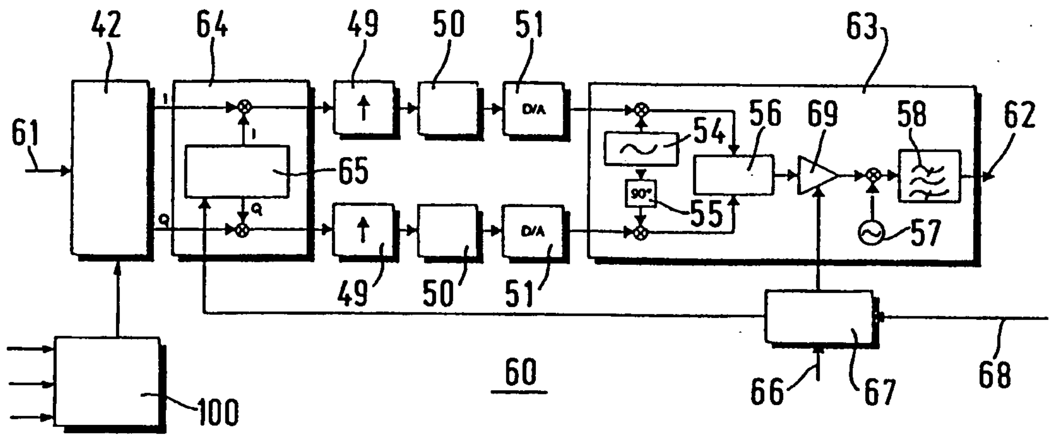
101
90

FIG. 4b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I
Q
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D/A
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67
68

FIG. 5a

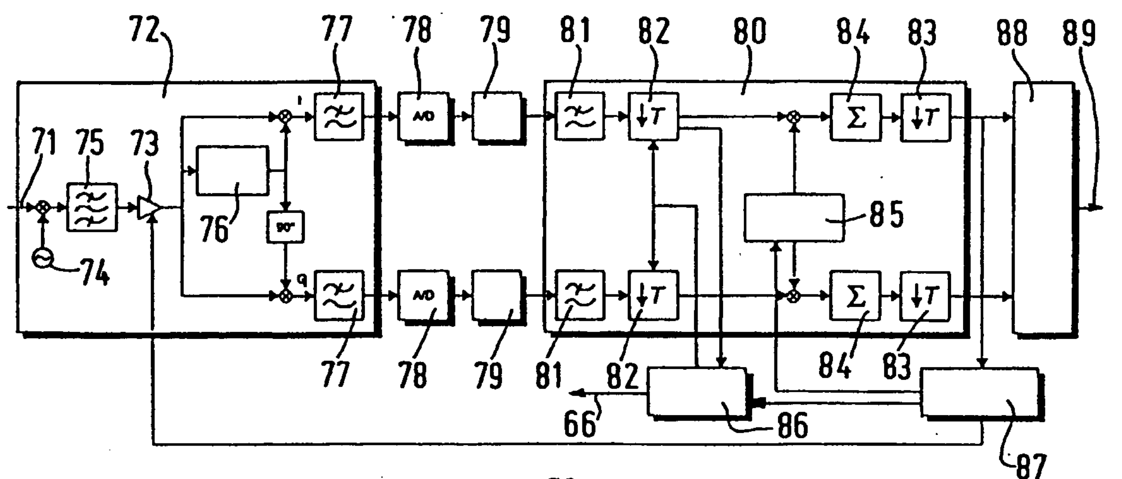
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FIG.5b

INTERNATIONAL SEARCH REPORT

Inte ..tio Application No
PCT/NL 98/00131

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SCHNELL M: "Hadamard codewords as orthogonal spreading sequences in synchronous DS CDMA systems for mobile radio channels" IEEE ISSSTA '94. IEEE THIRD INTERNATIONAL SYMPOSIUM ON SPREAD SPECTRUM TECHNIQUES AND APPLICATIONS (CAT. NO.94TH0604-9), PROCEEDINGS OF IEEE 3RD INTERNATIONAL SYMPOSIUM ON SPREAD SPECTRUM TECHNIQUES AND APPLICATIONS (ISSSTA'94), OULU, FINLAND, 4-6 JU, ISBN 0-7803-1750-5, 1994, NEW YORK, NY, USA, IEEE, USA, pages 505-509 vol.2, XP002047546 see abstract see paragraph 1 see paragraph 3 --- -/--	1,2,6, 10,11,15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 1998	09/07/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bossen, M

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INTERNATIONAL SEARCH REPORT

Inte. .io. application No
PCT/NL 98/00131

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 496 007 A (NIPPON ELECTRIC CO) 29 July 1992 see abstract see page 2, line 21 - line 35 see page 3, line 23 - line 53	1,10
A	US 5 440 542 A (PROCTER LEE M ET AL) 8 August 1995 see abstract	4,5,13, 14

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte ...do ...pplication No
PCT/NL 98/00131

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0496007 A	29-07-1992	AU 636190 B	22-04-1993
		CA 2034634 C	07-02-1995
		AU 6986191 A	30-07-1992
		DE 69120794 D	14-08-1996
		DE 69120794 T	07-11-1996
		US 5245612 A	14-09-1993
US 5440542 A	08-08-1995	NONE	